Impacts of broadscale weed control and fertilisation at establishment on survival and growth of second rotation pines

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Summary An experiment which examined the responses of second rotation *Pinus radiata* and *P. pinaster* to strip weed control vs. broadscale weed control and fertilisation treatments at establishment was commenced in 1996 on the coastal sand plain near Harvey, Western Australia.

Initial broadscale herbicide applications and subsequent spot applications were effective in maintaining the weed control plots weed-free for the duration of the experiment. Survival was reduced in both the *P. radiata* and *P. pinaster* when only partial (strip) weed control was used. After four years mean survival in the total weed control treatment was 95% for *P. radiata* and 92% for *P. pinaster*, while in the strip weed control treatment it was 43% and 75% respectively. The broadscale application of fertiliser had no effect on survival for either species. Height growth was reduced in the absence of complete weed control for both *P. radiata* and *P. pinaster*. The broadscale application of fertiliser had no effect on height growth for either species. The significant decreases in both survival and height growth in the absence of complete weed control and the lack of response to fertiliser for both species indicated that competition from weeds early in the second rotation was mainly for water.

Keywords Weed control, fertilisation, survival, height, *P. radiata*, *P. pinaster*.

INTRODUCTION

There is currently 3300 ha of *P. radiata* and 2200 ha of *P. pinaster* growing on the coastal sand plain south of Perth, Western Australia. Of this 58% and 86% respectively are still in their first rotation.

On the deep coarse sands of the Swan Coastal Plain the major limitation to survival and growth of pines is water availability (Havel 1968, Butcher 1980, McGrath *et al.* in press). These sands are inherently infertile with low concentrations of N, P and organic carbon (McGrath *et al.* in press). The deep porous nature of these soils and the intense winter rainfall makes them particularly susceptible to the loss of soluble nutrients by leaching. The competition between weeds and young pines for water and nutrients on water limited sites and the resultant reduced growth and mortality has been well documented. A study by Sands and Nambiar (1984) showed that herbaceous weeds and *P. radiata* competed for the same water supply at establishment. However, the competition decreased in subsequent growing seasons as the pines developed deeper roots and accessed water stored lower in the soil profile. Nambiar and Zed (1980) reported that in *P. radiata* plantations, competition with annual herbaceous weeds at establishment resulted in up to 40% mortality in the first year. On a first rotation site located on the Swan Coastal Plain north of Perth, Western Australia, Butcher (1980) found that native woody shrubs were not detrimental to *P. pinaster* growth when adequately controlled by mechanical cultivation at establishment, allowing the tree root system to dominate. On a non water-limited site, Smethurst and Nambiar (1989) found little difference in needle water potentials of *P. radiata* trees between complete and strip weed control despite large differences in growth. They attributed the differences in tree growth to direct competition for nitrogen between the trees and weeds.

One of the main differences between first and second rotation plantation sites on the Swan Coastal Plain is the difference in the suite of weeds. In the first rotation the weeds were mainly native woody weeds, however in the second rotation the weeds were mainly rapid growing annual and perennial exotics, similar to those found in agricultural areas. These weeds, in particular inkweed (*Phytolacca octandra* L.) and rose pelargonium (*Pelargonium capitatum* (L.) L'Her.) compete strongly for water and nutrients in the first few years after plantation establishment.

This experiment aimed to determine the effect of total weed control and broadscale fertilisation on tree growth and survival compared to standard strip weed control and spot fertilisation during the first years of the second rotation. The experiment also aimed to determine any differences in tree growth and survival between *P. radiata* and *P. pinaster* on similar sites with the same treatments.

MATERIALS AND METHODS

An experiment was established in 1996 on the coastal sand plain near Harvey, Western Australia (33° 05' S;

115° 45' E). Mean annual rainfall at this site is 900 mm with a mean annual evaporation of approximately 1800 mm. The experiment, which ran for four years, was established on two separate sites, approximately 200 m apart, in adjacent compartments of Myalup plantation. Site 1 was planted with *P. radiata* and site 2 with *P. pinaster*. Soils are Karrakatta sands, yellow phase (site 1) and grey phase (site 2) (McArthur 1991) characteristically coarse grained, highly permeable podzols. A factorial combination of two weed control and three fertiliser treatments were replicated three times giving a total of 18 plots at each site (Table 1). Treatment plot areas were 0.06 ha (25 m × 8 rows (24 m)), with an internal measurement plot of 0.0187 ha. Measurement plots contained a mean of 24 trees with a mean initial stocking of 1283 stems per hectare. Height and survival were measured twice in the first year and annually thereafter.

The broadscale weed control treatment using Roundup™ (glyphosate) at 4 L ha^{-1} and Brush-off™ (metsulfuron-methyl) at 15 g ha^{-1} was applied one month prior to planting and plots were maintained weed free for the duration of the trial by the spot application of Roundup (50:1 mix) and Vorox™ (atrazine/amitrole) when required. Standard establishment practice of strip spraying and spot fertiliser application was applied to all plots one month after planting. Strips were sprayed by hand using 5 L ha^{-1} Gesaprim™ (atrazine) and Vorox and each tree received a spot application of 22 g N and 10 g P. Broadscale fertiliser treatments were applied in early spring of the second year.

Weeds differed between sites, but were generally even over each site. Site 1 contained predominantly geranium (*Pelargonium capitatum*), and inkweed (*Phytolacca octandra*), with some annual ryegrass (*Lolium rigidum* Gaudin) and sorrel (*Acetosella vulgaris* Fourr.). Site 2 was predominantly annual ryegrass and blue lupins (*Lupinus cosentinii* Guss.), with some rose pelargonium, inkweed and the native woody shrub *Jacksonia sternbergiana* Huegel.

Statistical analysis Analysis of variance of mean tree heights and survival was used to assess the differences among; weed control treatments; fertiliser treatments; and the interaction between these treatments. To hold with the assumptions of normal distribution for analysis of variance, the survival data were arcsine transformed. Systat statistical software was used for the analyses.

RESULTS

Height growth Height growth was significantly reduced ($P<0.001$) in the absence of total weed control for both *P. radiata* and *P. pinaster*. The broadscale application of fertiliser had no significant effect on height growth, for either species, with or without total weed control. In the absence of weeds, the four-year mean height increment for *P. radiata* (485 cm) was significantly greater ($P<0.001$) than *P. pinaster* (392 cm). Significant differences between the species began in the first year and were maintained throughout. Without total weed control the four-year mean height increment for *P. radiata* (210 cm) was significantly lower ($P<0.001$) than *P. pinaster* (314 cm), however the differences in annual height increments did not begin until the second year (Figure 1). Reduction in height growth due to weed competition was 57% and 20% for *P. radiata* and *P. pinaster* respectively. In each of the four years of this study, height mean annual increment (MAI) was significantly different ($P<0.001$) between the total weed control and strip weed control treatments for both species.

Survival Survival was significantly reduced in the absence of total weed control in both the *P. radiata* ($P<0.001$) and *P. pinaster* ($P<0.05$). At the end of the first summer (April 1997) mean survival in the total weed control treatment was 96% for *P. radiata* and

Table 1. Weed control and fertiliser treatments applied at both sites.

Weed control	Broadscale fertiliser
Strip weed control	Nil
	Agras at 1000 kg ha^{-1}
	Agras at 2000 kg ha^{-1}
Broadscale weed control	Nil
	Agras at 1000 kg ha^{-1}
	Agras at 2000 kg ha^{-1}

Agras contains 17% N and 7.4% P.

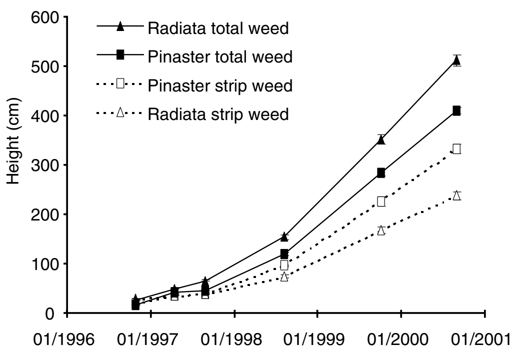

Figure 1. Height growth (cm) of *P. radiata* and *P. pinaster* with and without complete weed control in the first four years after planting.

92% for *P. pinaster*, while in the strip weed control treatment it was 59% and 73% respectively. Survival did not decline further in the *P. pinaster* plots in either the total weed control or strip weed control treatments or the *P. radiata* total weed control treatment for the remainder of the trial. Survival in the *P. radiata* strip weed control plots continued to decline over the second summer (97/98) and by August 1998 mean survival was only 44% (Figure 2).

There was no difference in survival between the species in the complete weed control treatment. In the strip weed control treatment survival in the *P. radiata* was significantly lower ($P<0.01$) than the *P. pinaster* after one year. The further decline in survival of the *P. radiata* maintained the significant difference. Survival for both species and all treatments remained constant after the second year. The broadscale application of fertiliser had no effect on survival for either species.

Weed control Initial broadscale herbicide applications and subsequent spot applications were effective in maintaining the weed control plots weed-free for the duration of the experiment. Follow up spot applications were only necessary in November and April in the first year after establishment and September of the second year (1997).

DISCUSSION

The significant decreases in both survival and height growth in the absence of total weed control and the lack of response to fertiliser for both species indicated that weed competition early in the second rotation was mainly for water.

Trees are most prone to water stress in their first summer after planting because they have shallow root systems and can not compete with weed root systems for water at depth (Sands and Nambiar 1984). This was seen at these sites with tree mortality in the absence of complete weed control being most severe over the first summer. The 41% mortality in *P. radiata* in the first year was the same as that found by Nambiar and Zed (1980) for this species on a similar site in South Australia. The weed associations in the *P. radiata* site which were predominantly woody perennials differed to that of South Australian site which were mainly herbaceous annuals, in particular, grasses. Rose pelargonium is a straggling, shrubby, perennial that is well adapted to growing in dry infertile sands (Hussey *et al*. 1997) and inkweed which is an erect woody perennial (to 2 m) which forms a well developed tap root (Lamp and Collet 1984) dominated the *P. radiata* site. The further decline in survival of *P. radiata* without complete weed control, by 15% over the second summer was most likely due to the continued competition for water throughout the profile between the trees and these deeper rooted perennial weeds. It was clearly evident that the standard practice of strip spraying with atrazine was not effective in reducing competition with woody perennial weeds in either the first or second years after planting. Results from a Forest Herbicide Management Group (2000) study into the movement of atrazine in the soil showed that in the Karrakatta sands at Myalup, atrazine movement was restricted to the surface 30 cm of the soil and had a half-life of only 25 days. Therefore strip spraying with atrazine would likely be ineffective in killing all deep-rooted perennial weed roots beneath the planting line. The lower mortality in the first year in the *P. pinaster* (27%) compared to the *P. radiata* (41%) and the lack of mortality in subsequent years is most likely the result of a combination of factors. Firstly, the predominance of shallow rooted annual weeds in the *P. pinaster* plots compared with the deeper rooted woody perennials in the *P. radiata*, restricting the most severe competition to the first year, and the greater drought tolerance of young *P. pinaster* compared with *P. radiata* (Hopkins 1960). Fertiliser treatments were applied in the second year and therefore had no influence on survival of either species in the first year.

The lack of response in either height growth or survival to fertiliser in either species with or without complete weed control suggests that nutrients were not limiting to young trees on these second rotation sites. In a Mediterranean climate, on deep porous sands with low water retentiveness, the single most important factor determining growth potential of trees is soil moisture availability (Butcher 1980). The same age *P. radiata* grown on a non water-limited site in Western Australia, that received total weed control and similar fertiliser treatments were taller than the *P. radiata* with total weed control in this study. Even in the absence

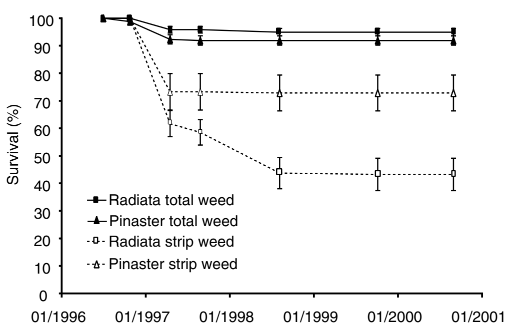

Figure 2. Survival (%) of *P. radiata* and *P. pinaster* with and without complete weed control in the first four years after planting.

of weeds on this porous sand, water availability appears to be limiting tree growth. Weed competition had a profound influence on height growth in both species during the first four years after planting and exacerbated the water limitation on tree height growth. The continued difference in height growth between the total-weed and strip-weed control treatments in both species for the duration of the study suggests that the competition for water was not restricted to the first year as found by Nambiar and Zed (1980).

In the absence of weeds, and therefore maximum water availability for these sites, *P. radiata*, exhibited significantly faster growth than *P. pinaster*. While this was reversed in the strip weed control treatment, the different composition of weeds between the sites and the lack of profile soil moisture data, makes it difficult to compare growth of the two species in this treatment. While the two species were growing on separate sites, the difference in soils between them is very small and relates mainly to differences in colour of the top 15 cm of the profile (McArthur 1991). It is therefore unlikely this difference would account for the large differences in height growth and survival between the two species growing on them.

CONCLUSION

Competition for water, rather than nutrients, by weeds appeared to be the critical factor in reducing both survival and height growth of the trees following second rotation establishment on these deep porous sands. Therefore, for optimum tree survival and growth, broadscale weed control is essential for establishment of second rotation pines where water is likely to be limiting.

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